FILE NO. 036290/US/2 - 475387-00017
PATENT

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

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| Inventor(s) | : | Guillermo J. TEARNEY et al. |
| Serial No. | : | 10/501,268 |
| Filed | : | July 9, 2004 |
| Entitled | : | APPARATUS AND METHOD FOR LOW COHERENCE RANGING |
| Group Art Unit | : | 2877 |
| Examiner | : | Denise Brown Anderson |
| Confirmation No. | : | 7475 |

I hereby certify that this correspondence is being deposited with the United States Postal Service as first class mail in an envelope addressed to Commissioner for Patents, United States Patent and Trademark Office, P.O. Box 1450, Alexandria, VA 22313-1450 on

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**DECLARATION UNDER 37 C.F.R. §1.131**

Sir:

We, Guillermo J. Tearney and Brett E. Bouma, declare as follows:

1. We are the co-inventors of the above-identified application.

2. The exemplary embodiment of the invention as recited at least in independent claims 48, 62, 70 and 84 pending in the above-referenced patent application were conceived of by us prior to September 7, 2000.

3. A written description of such exemplary embodiments of the invention which included every element recited at least in independent claims 48, 62, 70 and 84 is present in the "Technology

Disclosure" document we prepared having a date of completion prior to September 7, 2000, a redacted copy of which is attached herewith.

4. The exemplary apparatus and exemplary method of the invention which included every element recited at least in independent claims 48, 62, 70 and 84 was physically implemented within the facilities of The General Hospital Corporation prior to September 7, 2000, thus reducing the invention to practice subsequent to the conception and prior to September 7, 2000.

5. The information that described the exemplary embodiments of the invention as recited at least in independent claims 48, 62, 70 and 84 was provided to the office of Corporate Sponsored Research & Licensing of The General Hospital Corporation for consideration subsequent to the reduction to practice and prior to prior to September 7, 2000.

6. To the best of our knowledge, the exemplary embodiments of the invention as recited at least in independent claims 48, 62, 70 and 84 was not publicly disclosed or offered for sale more than one year from the filing date (i.e., January 11, 2002) of the U.S. Patent Application No. 60/347,528, from which the present patent application claims priority.

7. We hereby declare that all statements made herein of our own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Date: 7/19/06

Guillermo J. Tearney

Date: 7/19/06

Brett E. Bouma

Technology Disclosure

REDACTED

Use of an axial line focus for high resolution, high depth of field optical coherence tomography.

## Introduction

Currently, the use of optical coherence tomography (OCT) is limited to the visualization of morphological structures within biological tissues. The imaging of sub-cellular features with OCT has not been demonstrated because of the relatively poor transverse resolution required to preserve depth of focus. The capability to perform high transverse resolution, large depth of field cross-sectional OCT imaging would permit application to early diagnosis of epitheleal cancers and other biomedical imaging diagnostics that require sub-cellular level resolution.

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## Technical Description

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### Basic Principle

An axial line focus, with a narrow diameter and large length, is generated. Used in conjunction with OCT, the diameter of the line focus determines the transverse resolution and the length determines the depth of field. As in standard OCT, the detection of light backreflected from sites along the axial focus is performed using a Michelson interferometer. When the light source has a finite spectral width, this configuration can be used to determine the axial location of the backreflection site. The axial resolution is determined by the coherence length of the light source.

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### Resolution

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The intensity distribution of light transmitted through a refractive axicon lens[4] is given by:

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[1] J.H. McLeod, J. Opt. Soc. Am 44, 592 (1954).
[2] J.H. McLeod, J. Opt. Soc. Am 50, 166 (1960).
[3] J.R. Rayces, J. Opt. Soc. Am. 48, 576 (1958).

$$I(r,z) = \frac{4\pi^2 E^2(R)}{\lambda} \frac{RSin(\beta)}{Cos^2(\beta)} J_0^2(\frac{2\pi r Sin(\beta)}{\lambda}), \tag{1}$$

where $E^2(R)$ is the intensity of the light incident on the axicon as a function of the radius R, $\lambda$ is the wavelength of the light, and $\beta$ is the half angle of thelight transmitted through the axicon. The cone angle $\alpha$ is related to $\beta$ and the depth of focus, $z_D$, by:

$$nSin(\alpha) = Sin(\alpha + \beta), \tag{2a}$$
$$z_D = R(Cot(\beta) - Tan(\alpha)), \tag{2b}$$

where n is the refractive index of the axicon. The above equations can be used to determine the diameter of the axial line focus. For plane wave illumination the focus diameter is:

$$d_0 = 0.766\frac{\lambda}{\beta}. \tag{3}$$

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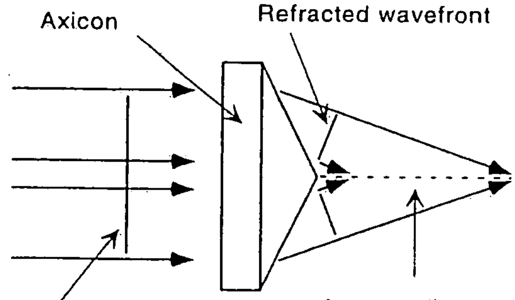


**FIGURE 1.** Schematic describing focusing using a refractive axicon. A collimated beam, incident fromthe left, is focused to an axial line with a narrow width and large depth.

By combining the high transverse localization (and weak axial localization) of an axicon with OCT (Fig. 2), an imaging system that provides high three-dimensional localization over large field sizes can be realized. Axial resolution for this imaging technique is determined solely by the coherence length of the light source[5] and is given by:

$$\Delta z = \frac{2Ln(2)}{\pi} \frac{\lambda^2}{\Delta\lambda}, \tag{4}$$

where $\Delta\lambda$ is the spectral width of the light source.

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[4] R. Arimoto, C. Saloma, T. Tanaka, and S. Kawata, Appl. Opt. 31, 6653 (1992).

[5] E.A. Swanson, D. Huang, M.R. Hee, J.G. Fujimoto, C.P. Lin, and C.A. Puliafito, Opt. Lett. 17, 151 (1992).

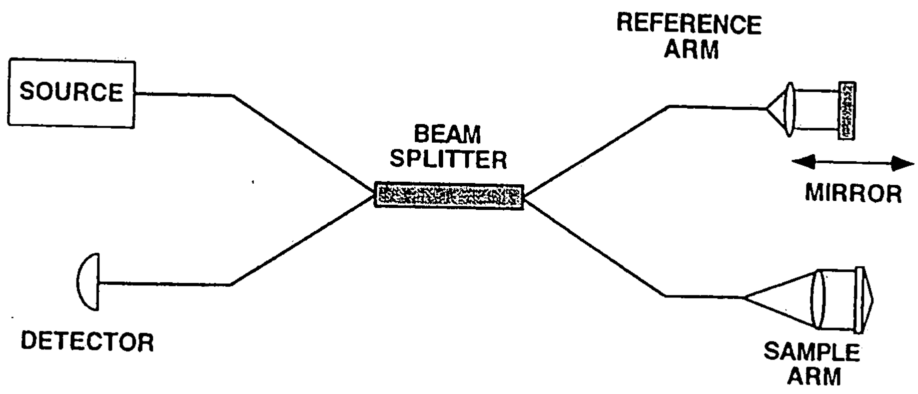


FIGURE 2. Schematic of OCT system with axicon optic in sample arm.

## Image Formation

A rough schamtic of the entire OCT/axicon system is depicted in Fig. 4a. All components, other than the axicon probe are standard to OCT. The use of OCT to determine the backreflection as a function of distance along the axial line focus provides a one dimensional raster scan. This is typically accomplished by scanning the length of the interferometer reference arm. An axicon has the property each axial location of the focus corresponds to a unique annulus at the input aperture of the axicon (Fig. 3). This relationship could allow the reference arm length scanning to be replaced by scanning an annulus of illumination at the axicon aperture.

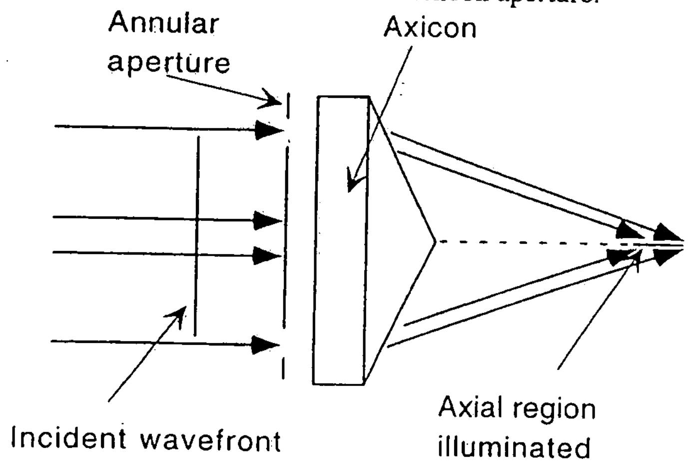


FIGURE 3. Schematic depicting relationship between axial location and annulus of illumination.

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